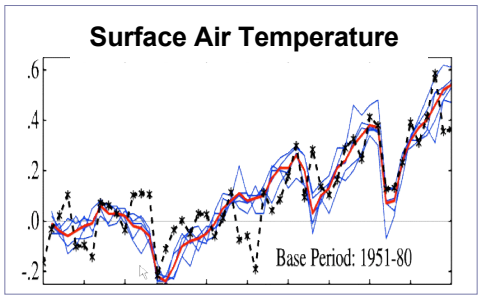
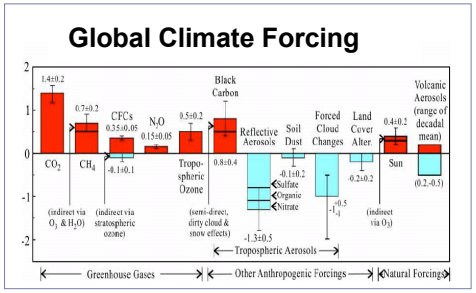
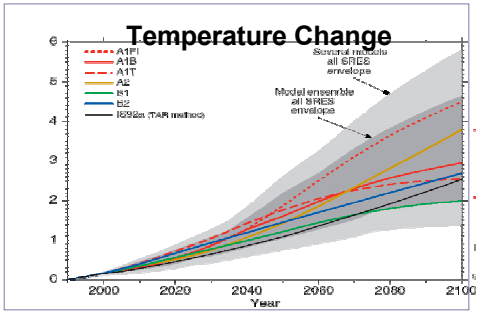
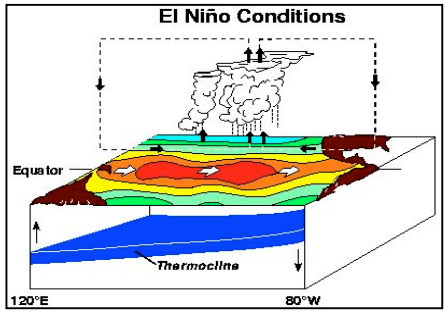
Climate Variability and Change

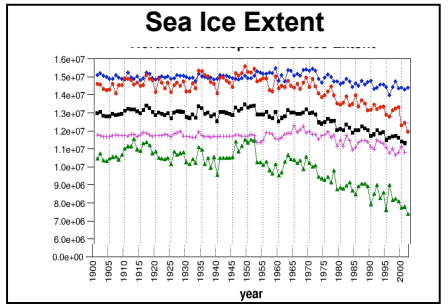


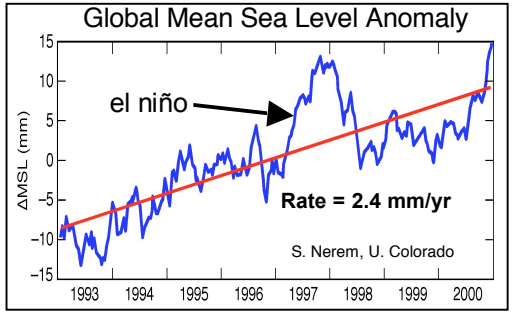




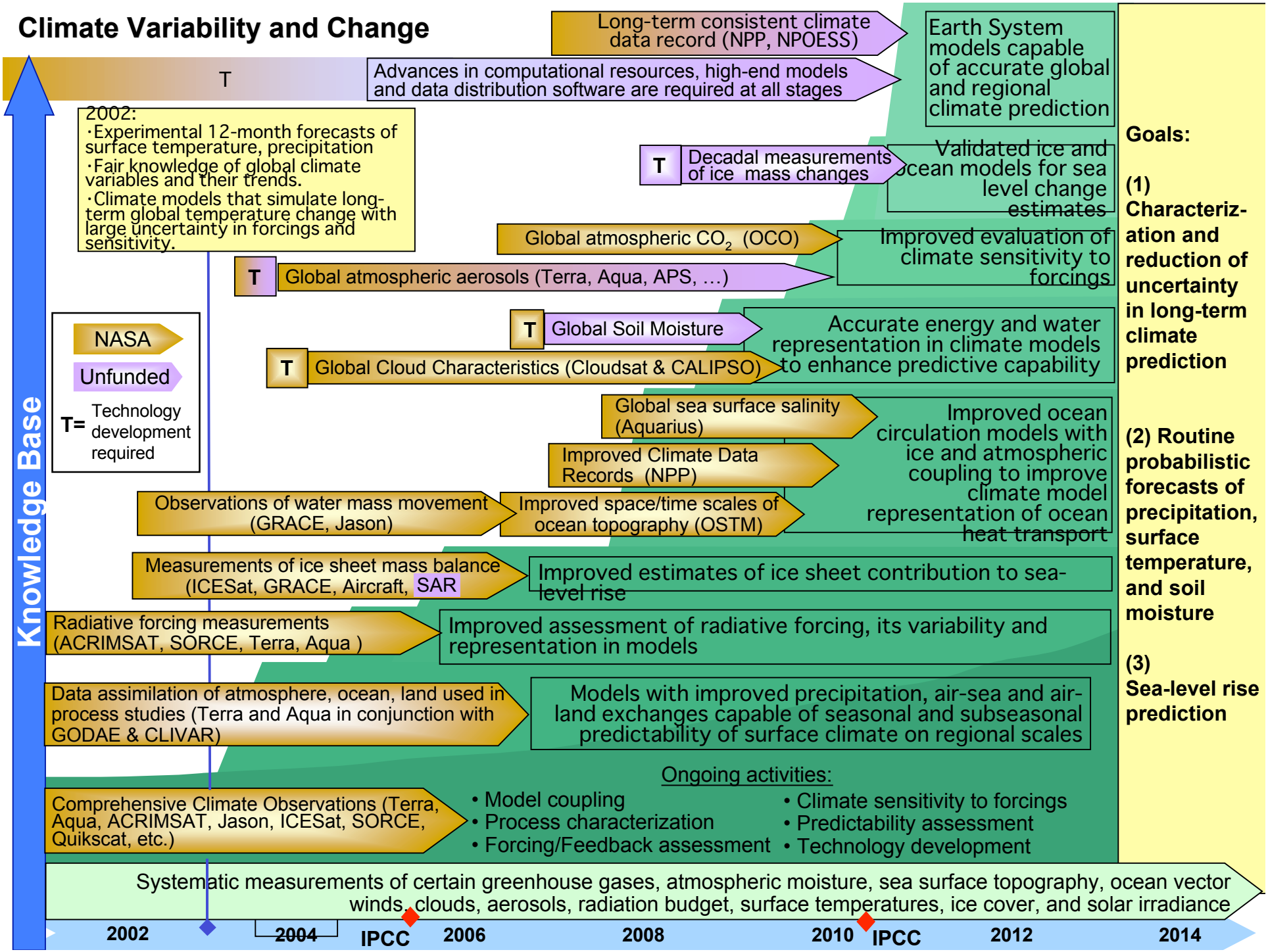
- **How is global ocean circulation varying on interannual, decadal, and longer time scales?**
- **What changes are occurring in the mass of the Earth's ice cover?**
- **How can climate variations induce changes in the global ocean circulation?**
- **How is global sea level affected by natural variability and human-induced change in the Earth system?**
- **How can predictions of climate variability and change be improved?**







Climate change is one of the major paradigms guiding Earth System Science today. NASA is at the forefront of quantifying forcings and feedbacks of recent and future climate change. Our comprehensive end-to-end program goes from global high-resolution observations to data assimilation and model predictions.


Climate Variability and Change
Knowledge Base
Long-term consistent climate data record (NPP, NPOESS)
Earth System models capable of accurate global and regional climate prediction
T
Advances in computational resources, high-end models and data distribution software are required at all stages
2002:
·Experimental 12-month forecasts of surface temperature, precipitation
·Fair knowledge of global climate variables and their trends.
·Climate models that simulate long-term global temperature change with large uncertainty in forcings and sensitivity.
T
Decadal measurements of ice mass changes
Validated ice and ocean models for sea level change estimates
Global atmospheric CO_2 (OCO)
Improved evaluation of climate sensitivity to forcings
T
Global atmospheric aerosols (Terra, Aqua, APS, …)
NASA
Unfunded
T= Technology development required
T
Global Soil Moisture
Accurate energy and water representation in climate models to enhance predictive capability
T
Global Cloud Characteristics (Cloudsat & CALIPSO)
Global sea surface salinity (Aquarius)
Improved ocean circulation models with ice and atmospheric coupling to improve climate model representation of ocean heat transport
Improved Climate Data Records (NPP)
Observations of water mass movement (GRACE, Jason)
Improved space/time scales of ocean topography (OSTM)
Measurements of ice sheet mass balance (ICESat, GRACE, Aircraft, SAR
Improved estimates of ice sheet contribution to sea-level rise
Radiative forcing measurements (ACRIMSAT, SORCE, Terra, Aqua)
Improved assessment of radiative forcing, its variability and representation in models
Data assimilation of atmosphere, ocean, land used in process studies (Terra and Aqua in conjunction with GODAE & CLIVAR)
Models with improved precipitation, air-sea and air-land exchanges capable of seasonal and subseasonal predictability of surface climate on regional scales
Ongoing activities:
Comprehensive Climate Observations (Terra, Aqua, ACRIMSAT, Jason, ICESat, SORCE, Quikscat, etc.)
• Model coupling
• Process characterization
• Forcing/Feedback assessment
• Climate sensitivity to forcings
• Predictability assessment
• Technology development
Systematic measurements of certain greenhouse gases, atmospheric moisture, sea surface topography, ocean vector winds, clouds, aerosols, radiation budget, surface temperatures, ice cover, and solar irradiance
2002
2004
IPCC
2006
2008
2010
IPCC
2012
2014
Goals:
(1) Characterization and reduction of uncertainty in long-term climate prediction
(2) Routine probabilistic forecasts of precipitation, surface temperature, and soil moisture
(3) Sea-level rise prediction

Anticipated Progress in Answering the Questions: Climate Variability and Change

Forward

Where we are now	Where we plan to be
Large uncertainties in tropospheric aerosol forcing. Good knowledge of greenhouse gases and their corresponding forcing.	Precise knowledge of greenhouse gases forcings and feedbacks (sea ice, water vapor etc.). Good knowledge of tropospheric aerosol forcing and cloud effects.
Climate models simulate long-term global temperature change with large uncertainty in forcings and sensitivity.	Comprehensive earth system models capable of simulating future climate changes based on different forcing scenarios with good confidence.
6-9 month forecasts of global surface temperatures and precipitation are conducted routinely	Routine operational integrated modeling and forecasting system for seasonal-to-interannual predictions using multiple satellite and *in situ* data streams.
Insufficient knowledge and representation of processes such as upwelling and surface heat, freshwater and the modeling of low level clouds	Enhanced global satellite observations of surface winds, heat, freshwater, radiation and vertical distribution of clouds and temperature to improve modeling of air-sea exchange and low-level clouds
Limited knowledge of partitioning of sea level rise including uncertainty of whether ice sheets are growing or shrinking	Decadal ice sheet mass balance estimates, improved assessment of contributions from glaciers and ocean thermal expansion with greatly enhanced sea level prediction capabilities

2002 ~ 2015

Anticipated Outcomes and Uses of Climate Models: Predicting Future Climate Variability and Change

Roadmap

Model Capability	Products / Uses for Decision Support
Comprehensive earth system models capable of simulating future climate changes based on different forcing scenarios with good confidence.	Quantitative options for reducing climate forcings provided to policy and management decision makers.
Integrated modeling and forecasting system for seasonal-to-interannual predictions using multiple satellite and *in situ* data streams.	Forecasts of risk of extreme events or prolonged wet or dry conditions.
Climate models that: - Reliably characterize regional effects of global climate change - Provide quantitative evaluation of climate sensitivity - Provide sources of prediction skill globally	Projections of changes in the climate system with sub-regional specificity and good reliability. --- Credible, useful analyses of climate forcings and feedbacks for a variety of policy-relevant "what if" scenarios.
Regional sea level rise prediction capability	Information for coastal planning and management